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METEOROLOGICAL STUDIES AT BRADFIELD

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I Environmental measurements

Introduction

In field studies designed to evaluate the effect of meteorological factors on livestock, long-term, inter-disciplinary projects are desirable but changes in grazing facilities, husbandry techniques etc add further dimensions of difficulty to those logistic problems of site maintenance and data acquisition (Smith 1970). However, it was Gloyne's (1963) conviction that, given sufficient data at frequent intervals, it should be possible to infer the basic features of at least the wind regime at a site after days rather than months or years and this philosophy was applied to the Bradfield (near Reading) meteorological survey.

Materials and methods.

The establishment of an instrument network was guided by the limitations imposed by the number and nature of the instruments, the necessity for monitoring sites, collecting data and the availability of staff. In both 1976 and 1977 all fields where lambs were allocated were instrumented although the network was extended in 1977. Run-of-wind cup anemometers (exposed at 2m height) and minimum thermometers (at 1m) were established near feed and watering areas and near significant hollows. Surveys with hand-held anemometers helped to establish a 'feel' for the wind regime. A chain of minimum thermometers was also established to monitor conditions within, and in the vicinity of, the ewe housing. Data were related to a 'reference' site established in Annis field (fig 1) which housed a raingauge, recording run-of-wind anemometer, grass minimum thermometer, maximum and minimum thermometers housed in a Stevenson screen and a minimum thermometer, screened simply and exposed at 1_m as in the other fields. During the critical neo-natal period daily readings were made. The wind exposure table, relative to Annis field is presented in Table 1; the influence of topography and tree configuration can be clearly seen. For example, a westerly flow is channelled into the low-lying, tree-lined hollow (K) in Annis field, the north/south orientated hollow in Rushall field R, Channels a southerly flow. The highly exposed nature of the feed area in Rushall (M) is apparent (winds from the SW up to 200% of those at the reference site).

Annis Cross and Bayleys Dene emerge as comparatively well-sheltered although Bayleys does have an exposed nature to winds from the south. Table 2 provides an indication of the relative shelter afforded at the various sites over periods of weeks.

Minimum temperature data showed the severity of 'frost hollows' in Rushall and Bayleys Dene compared with other sites (both generally 1 to 2°C colder on radiation nights). Minimum temperatures within the ewe housing were about 1°C above ambient irrespective of the presence of the ewes, pointing to effects due to the thermal capacity of the building and its concrete surround, the heat output from the ewes being of second order importance.

The gradation of minimum temperatures on radiation nights illustrated the drainage of cold air (Katabatic flow) down the south facing slope (of about 1 in 7) on which stood the housing. (To minimise the effects of pooling of cold air within the house it was suggested that the north side could be protected by straw bales and the south side left relatively uncluttered to aid air drainage).

II Weather influence on lambs.

Introduction

Weather affects farm livestock directly as a result of exposure to climatic rigours and indirectly in its influence upon food availability (Obst and Day, 1968, Hugh-Jones 1976). A measure of the thermal demand of an environment is given by the metabolic response it elicits from, the animal; this response thus represents an integration of the individual 'weather elements'. Heat exchange calculations are complex (eg Blaxter et al 1964) and further complicating factors are the mobility of stock, enabling shelter to be sought and their microclimate ameliorated (Michael 1960), the state of the birthcoat/fleece (Purser and Karam 1967), food availability and the physiological state of the animal at the time.

The total environmental effect experienced by a lamb will fluctuate from hour to hour with variations in air motion, temperature and radiative effects and the intensity and duration of the rainfall as has been demonstrated by Webster (1971) on experiments with heated models of animals.

Climate chamber research (Alexander 1964) and field observations (Slee 1977) demonstrate that almost all newborn lambs are subject to cold stress due to the mutually reinforcing effects of cold and energy depletion. Small undernourished lambs, particularly breeds with short birthcoats, can be at risk even in quite moderate weather conditions such as those generally encountered by lowland flocks in SE England. Some form of shelter, even that afforded by scrub and small bushes, is considered an important factor in reducing neo-natal lamb deaths, (Cresswell and Thomson 1964, Egan et al 1972). It has been noted, too, that daily grazing patterns often reflect the efficacy of geomeorphic shelter (Munro 1962).

The environment becomes potentially lethal when heat loss from the lamb exceeds its 'summit metabolism' (the maximum rate of heat production the lamb can summon). Although calculations of heat loss might be considered on an hour-to-hour basis the actual rain/wind/temperature regime being experienced by the lamb can be only roughly estimated in view of, for example, the varying wind and turbulence regime across a field at lamb height and the shelter-seeking capacity of the lamb. Further, the relative importance of short period high stress and moderate stress over an extended period is arguable; the capacity of the lamb to increase heat production and/or maintain summit metabolism will be important factors. Average daily wind speeds and rainfall data were thus used as offering a satisfactory measure of the relative severity of the environment.

'Summit temperature' data

The heat production graphs of Alexander (1964) apply to yound Merino lambs (shown by Sykes et al (1976) to display different thermoregulating ability from British breeds); the data though are considered to have reasonable applicability to the Bradfield situation (Slee, private communication). At the very least the ambient temperatures readily extracted from the graphs - required to induce 'summit metabolism' will present a useful qualitative guide to days when 'weather' would have led to problems in the maintenance of homeothermy.

These 'sumit temperature' data discussed are displayed in Fig 3a, b in conjunction with measured minimum temperature data (although the maximum thermal demand due

to wind and rain would not necessarily occur in conjunction with minimum temperature conditions). Also displayed are days with periods of high thermal stress, over a few hours, deduced from rainfall and wind speed data analyses over 6 hour periods on rain days.

Bradfield Weather

The basic weather elements measured at the feed area in Rushall field in the 1976 and 1977 seasons are displayed in fig 2a,b. A brief description of some aspects of the weather in southern England in the pre-weaning periods will set fig 2 in context.

1976 After a mild, dry winter the spring and summer of 1976 continued with exceptionally low rainfall. Less than 50% of average rainfall fell in March and May; April and June had only 25% of average. At Bradfield there were only 14 days with rain between mid-March and the end of May and only 8 had more than 0.5 mm. Strong westerly winds set in for two weeks at the end of March followed, in the second half of April, by a northerly regime. Temperatures were somewhat below average in March and April but well above in May and June.

1977 Air and earth temperatures were well above average from February until mid-March. A cold spell then set in until early April (encouraging extended stays in the housing for lambs born then). Late April produced strong, wet westerly winds which slackened off during the first half of May. A dry northerly regime became established until early June. In the mid-March to end of May period there were 43 days with rain at Bradfield of which 37 had rainfall of more than 0.5 mm.

Discussion of data

The majority of field deaths in 1976 occurred to twin lambs in Rushall; of these 20 deaths however only 6 were analysed as being due to chilling/starvation. Rushall is very exposed to winds from the SW (Table 1) with several low lying hollows prone to cold air drainage; temperatures up to 3°C below those at the feed area have been recorded on calm frosty, nights.

Annis Cross is a comparatively well sheltered site for most wind directions (Table 1) although for winds from the north-east quadrant the feed area at Rushall is a

slightly better proposition that Annis Cross (and most other areas of Rushall); apart from the Northerly period in second half of April, Annis Cross winds were often only 50% those of Rushall. Over the 2½ month period, tabulated in Table 2, the figure averaged out at about 75%.

Over corresponding periods in 1976 and 77 Annis field reference site recorded about the same total run of wind (~ 10,000 miles); 82% of this total was recorded in Annis Cross in 1976 and 71% in Bayleys in 1977. No triplets succumbed in Annis Cross yet 10 died due to chilling/starvation in Bayleys in 1977. A similar number of twins died in Rushall in both years, the total run being slightly greater in 1977 (118% of reference, compared with 106% in 1976 and 1977 respectively).

The major difference between the two seasons was the rainfall; a wet birthcoat dramatically increases the Lower 'summit' temperature, T_s, according to Alexander's graphs.

The environmentally induced stress represented by T_s for 2 kg lambs is shown in fig 3; studying the values of T_s compared with, say, minimum site temperature for two or three days prior to a field death due to chilling gives an indication of the history of thermal stress in the lamb. (Table 3). Records shown that .6 out of the 20 'chilling' deaths occurred on days with apparently little or no environmental stress. Since several lambs died after only 2 or 3 days at pastures it is reasonable to consider the thermal stress encountered over those 2 or 3 days a contributing to death.

In the table, A represents a day with T_s above T_{min}, B a day with T_s close to but below T_{min} and X a day with T_s at least 10°C below T_{min}. Days which had short term high stress periods are shown.

In 1976 4 out of the 6 chilling deaths each experienced A or B conditions on one of the 3 pre-death days; there was apparently no indication of a thermal stress history in the other two lambs. In 1977 on the other hand, thermal stress is indicated for most low weight lambs on at least two days prior to death up to early April. The deaths on 5 and 13 April were apparently associated with only one 'A' period and that was 2 and 3 days respectively prior to death. Of all chilling death that on 25 March had the weakest link with thermal stress history (2 B's). The low or nil chilling death incidence of single lambs in both years probably reflects the influence of the higher average birth weight in lowering T_s. A complete table of 3-day thermal stresses was

completed by allocating 'scores' of 2, 1 and 0 respectively to the stress represented by A, B and X. (ie 3 days of high stress, A, accumulates 6).

It becomes clear that there were occasions of comparatively high stress that did not preceed death just as there were occasions when low stress did proceed death. It is sensible, therefore to compare the ratios of the number of 'death days' to the number of high and low stress 3 day periods (Table 4). Now a pattern emerges: over the period 13 March - 30 April (lambs still of relatively low weight) about 1 in 2 high scoring periods resulted in death; only 1 in 7 low scoring periods did so. These high scoring periods accounted for 70% (14 out of 20) of the lamb deaths. The low stress/increasing lamb weight in May further depressed the ratio deaths in low scoring periods so that from 13 March to 31 May the corresponding was still 1 in 2 for high scoring periods (1 in 3 for $ $\geq$ 4) but only 1 in 13 low scoring periods. (The trend is still clear but not quite so favourable when two day stress periods are considered). No deaths were recorded in May 1977. Daily winds runs were low in Bayleys in the first half of that month (12 days each with less than 100 miles) although associated with 12 rain days. Wind runs in the second half of May, in a dry north-easterly regime, were on average double those in the first half (see table 2).

The integrated effect of the wind/rain régime in each half of the month was to maintain T_s well below the T_{min}. The potential for thermal stress would have been further diminished by the icreased weight of the lambs by this time of the season.

Finally, recalling the high earth temperatures and rainfall of early 1977 - conditions encouraging early flush of grass growth, it is interesting to note the comparatively high losses (10) amongst ewes due to hypomagnesemia.

Summary of Meteorological Studies

The lamb deaths due to field chilling in the Bradfield study in 1976 and 1977 seasons have been related in a semi-quantiative manner to the 'summit temperature' (deduced from averaged meteorological parameters) induced by the environment. Assumptions and inaccuracies due to the inherent problems of applying T_s data have been discussed. The differences in the thermal stress environment between the two seasons have been indicated and shown to relate qualitatively at least to the distribution of deaths between the fields and seasonally. Incidences of lamb deaths in 1977 relate well to the accumulation effect of thermal stress over the preceding 2 or 3 days.

The meteorological data have also demonstrated that substantial variations in wind regime (and frost potential) can occur evenbetween adjacent fields. Higher ground (eg Annis Cross) is not necessarily more exposed nor lower lying pastures (eg Rushall) more sheltered. (Such influences of various features of the landscape on airflow have been remarked on by Gloyne (1976), Hogg (1964-65) and others). Such meteorological surveys at the planning stages of enterprises could be of considerable value in aiding the selection of feeding and animal housing sites, in allocating weakling stock to suitable pastures and in assessing the need for shelter belts.

Any comments or suggestions on this paper should be referred to the author.

Meteorological Office
Bracknell
May 1978

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Table 1

Run-of-wind as a function of direction expressed as percentage ratio of the wind at the reference site.

Table 2

Runs-of-wind, R miles, over half-monthly periods at various sites in 1976 and 1977 seasons. Approximate wind directions for the periods are given together with number of days with rain.

Table 3

Thermal stress over the 3-days prior to lamb deaths adjudged to be due to chilling, based on Summit Temperature data for 2 kg lambs by Alexander (see text). Short period, high stress occasions are boxed.

Table 4

Ratio of number of days on which lamb deaths occurred to the number of periods of 3-days with the stated 'thermal stress' scores. The numbers of lamb deaths are shown.

TABLE 1

Run-of-wind at Bradfield

Run-of-wind as a function of direction
(expressed as a % ratio of the wind at reference site in that direction)

Direction	Annis Cross J	Bayleys Dene G	Annis Field (hollow) K	Rushall Feed Area M,	Rushall Bottom P	Rushall Hollow R	Owl Pit Top A	Owl Pit bottom E
N to NE	73	68	49	73	82	72	76	76
NE to E	67	70	53	74	91	80	86	83
E to SE	59	69	35	89	104	74	114	114
SE to S	63	120	49	178	127	124	121	116
S to SW	98	113	70	206	151	113	111	149
SW to W	113	95	91	175	147	93	100	170
W to NW	81	61	104	108	97	58	73	120
NW to N	75	58	49	103	91	71	72	82

TABLE 2

Half Monthly Runs-of-Wind.R, (miles)

X	Rain days	1976 Annis X J	Rushall M	Annis Field H	direction	Rain days	1977 Bayleys C	Rushall M	hollow R	bottom P	Owl A	E	Annis H	K	
1-15 March		641	1084	1542	E→S→N		1970	3220	1819	2281	1777	2125	1582	957	SW
16-31	1	1724	2468	1893	N→W	12	1626	2260	2072	2296	2191	1995	2115	932	NE
1-15 April	5	1252	1883	1628	W→NW	6	1311	2817	1532	2370	1536	2267	2104	1950	NW
16-30	0	1677	1390	2245	N	10	1532	2880	1745	2401	1589	2557	1693	1388	SW
1-15 May	2	1220	2154	1480	W	12	942	1856	1185	1583	1126	1619	1297	1096	NW
16-31	5	1328	2656	1731	W	2	1992	2124	2249	2431	2450	2247	2914	1471	N→NE
Total 16 Mar-31 May		8201	10551	9977			7203	11937	8783	12081	8892	10695	10123	7037	

TABLE 3

3-day thermal stress sequences prior to lamb deaths from chilling
(based on critical temperature data by Alexander for 2 kg lambs)

Short period high stress occasions boxed.

1976					1977				Number of deaths
March					March	16	A	A	A	2
	22	X	X	X		18	A	A	A	1
	28	B	X	X		20	A	A	B	4
April	1	X	X	A		21	A	B	[B]	1
	6	X	A	X		22	B	[B]	B	1
	14	X	X	A		25	B	B	X	2
	21	X	X	X		28	X	A	A	1
						29	A	A	A	1
						30	A	A	X	1
					April	2	X	[A]	A	1
						3	[A]	A	X	1
						4	A	X	A	1
						5	X	A	X	1
						13	A	X	X	1
						15	X	A	A	1

Table 4

3 day score, S	≤ 3	≥ 4	≥ 5	6	Total lamb chilling deaths
13 – 31 March lamb deaths:	3 : 8 4	6 : 11 10	4 : 6 8	2 : 4 3	14
13 March – 30 April lamb deaths:	4 : 27 6	10 : 22 14	4 : 9 8	2 : 4 3	20
13 March – 31 May lamb deaths:	4 : 52 6	10 : 28 14	4 : 11 8	2 : 4 3	20

left hand column: number of days when a lamb death occurrred.

right hand column: number of periods of day with the stated score.

Legend

Fig 1 Map of Bradfield showing the siting of meteorological instruments (X). Reference site was in Annis field. The 1976 network included only Annis Cross and Rushall field area (M), it was extended in 1977.

Fig 2 'Weather' in Rushall field in each year on a daily basis. Runs-of-wind (in miles) are shown in conjunction with the occurrences of ground and air frost and rain days. Dates of lamb deaths due to chilling are indicated.

Fig 3 Relationship between 'summit' temperature 'T_s' and lamb deaths. Ordinate is (T_s - Minimum Temperature). Periods of enhanced short period thermal stress are indicated.

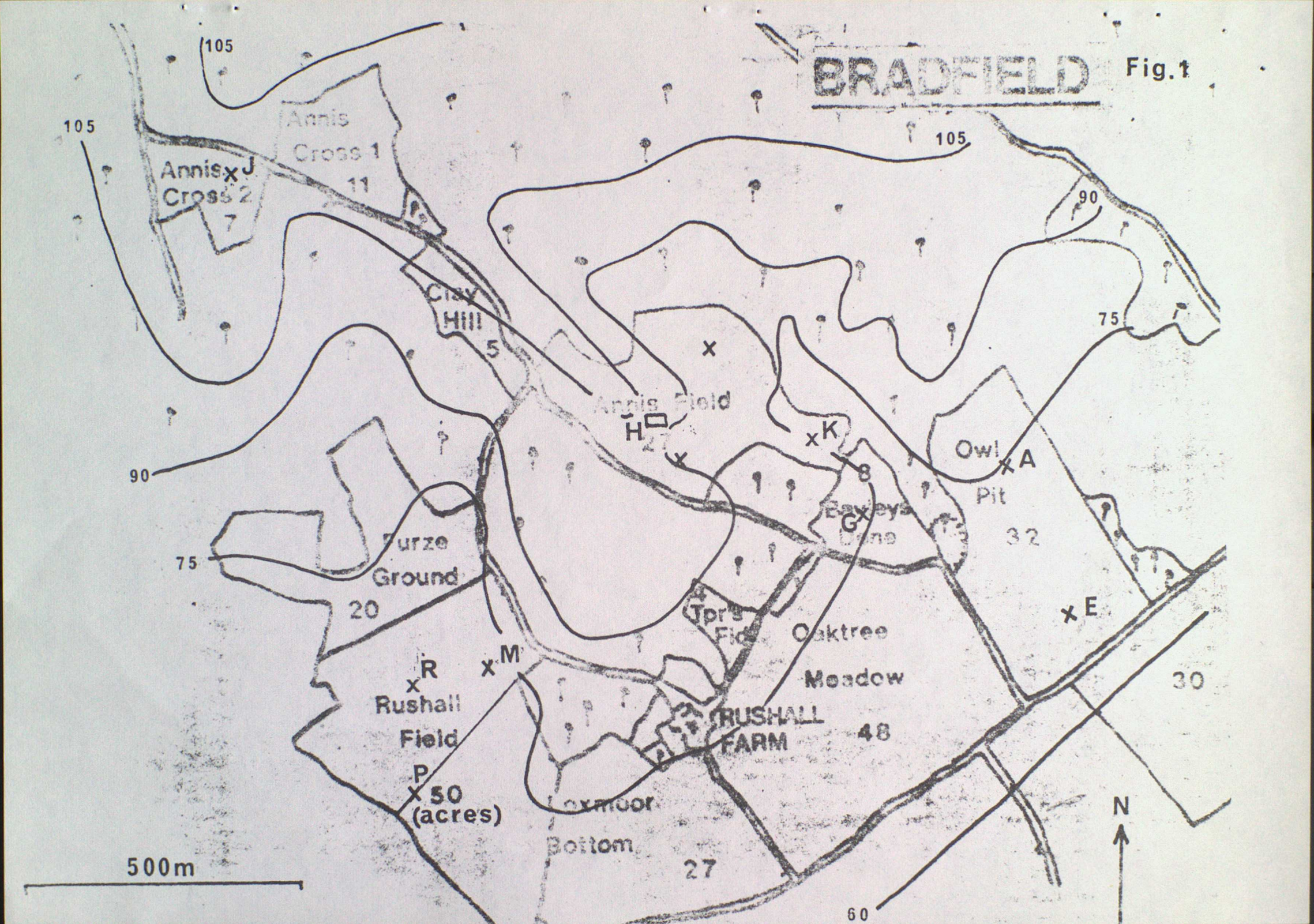
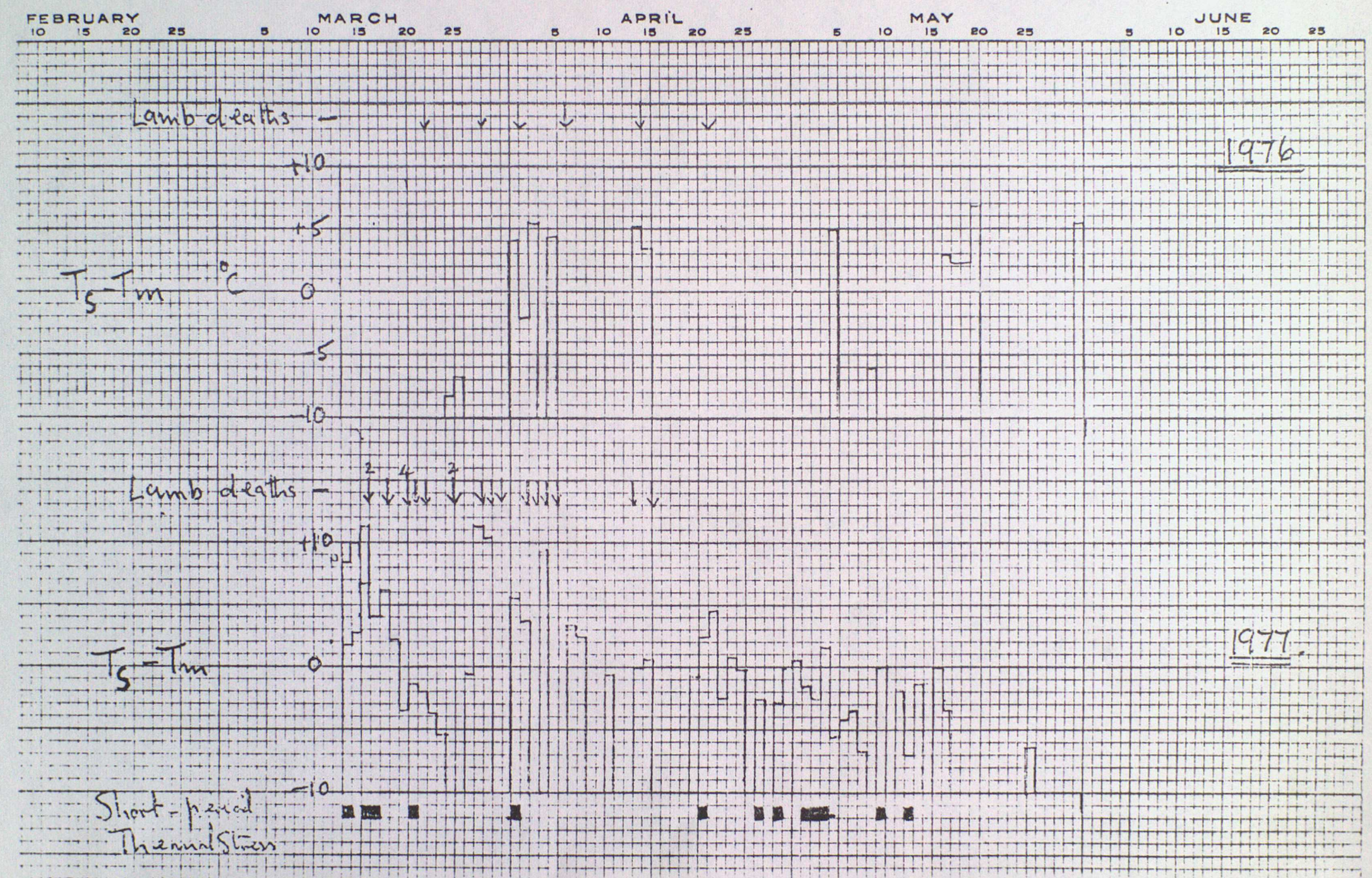
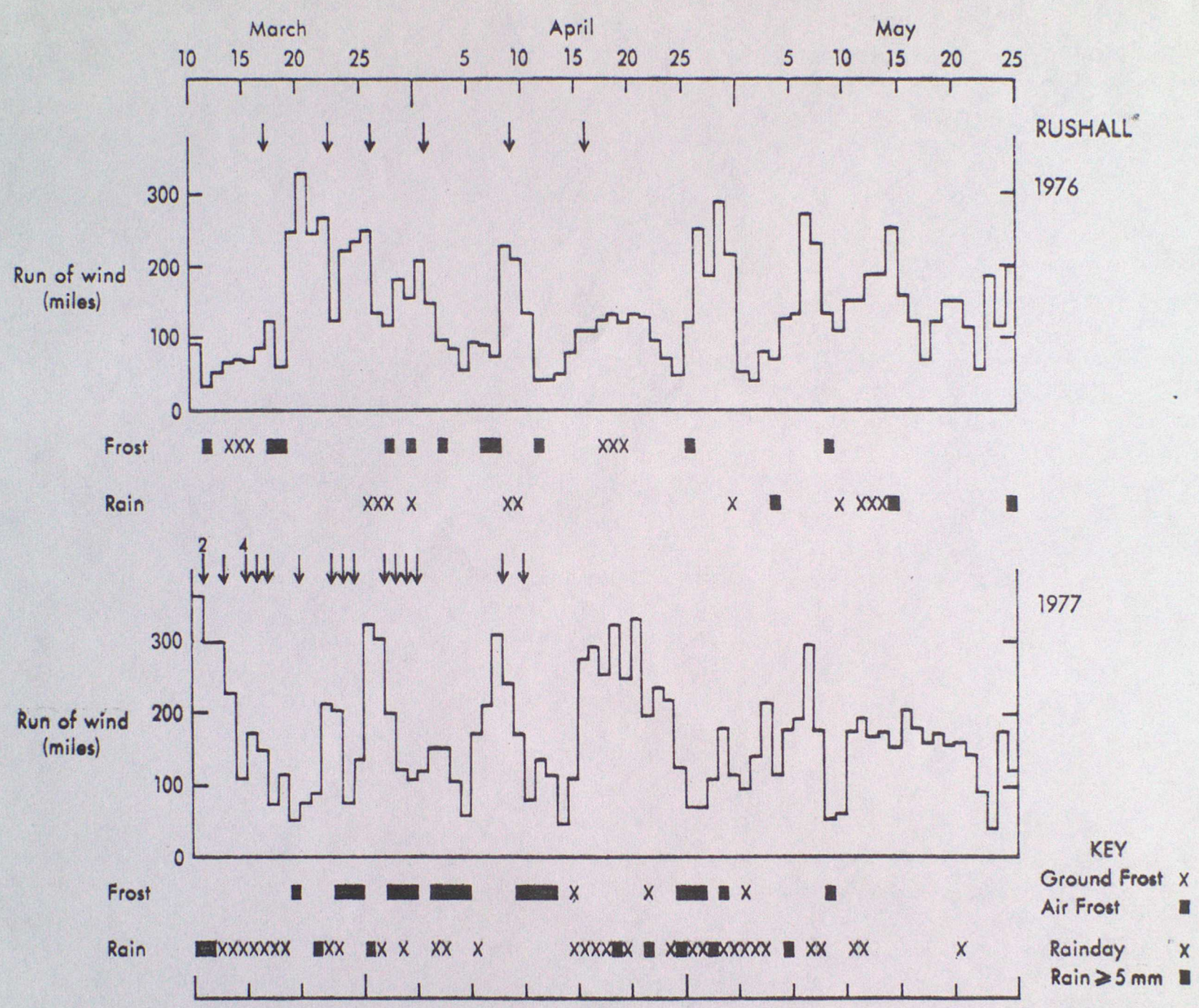
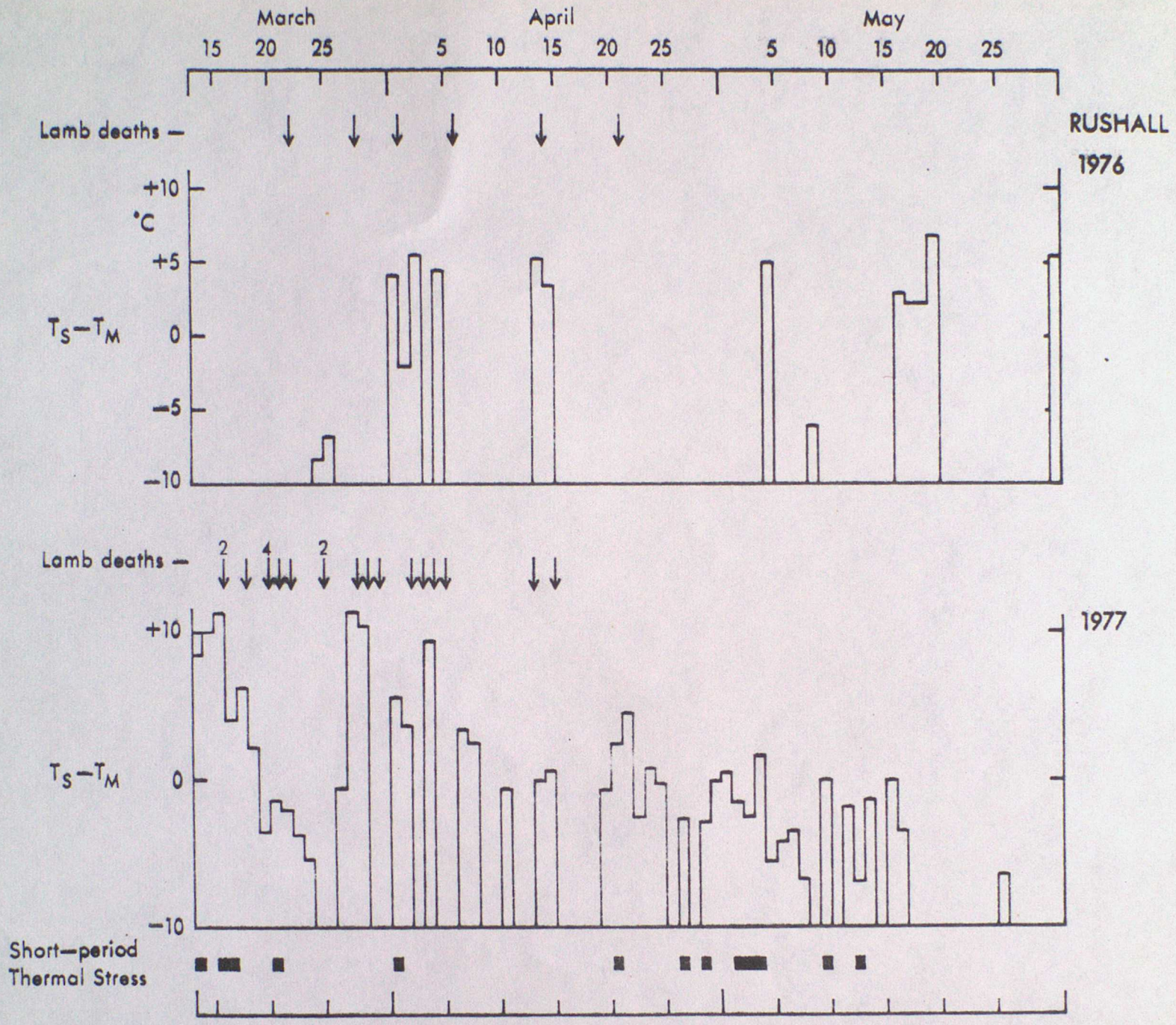

BRADFIELD
Fig.1
105
105
105
90
90
75
75
60
Annis Cross 1
11
Annis Cross 2
7
J
Clay Hill
5
Annis Field
H
K
8
Bayleys Lane
G
Owl Pit
A
32
Furze Ground
20
Upr's Fld
Oaktree Meadow
E
30
R
M
Rushall Field
P
50 (acres)
RUSHALL FARM
48
Foxmoor Bottom
27
500m
N

Fig 3.

(Summit ~~Critical~~ Temperature — Minimum Temperature).




March
April
May
10 15 20 25 5 10 15 20 25 5 10 15 20 25
RUSHALL
1976
Run of wind (miles)
300
200
100
0
Frost
Rain
1977
2
4
KEY
Ground Frost X
Air Frost
Rainday X
Rain ≥ 5 mm


March
April
May
15
20
25
5
10
15
20
25
5
10
15
20
25
Lamb deaths –
RUSHALL
1976
+10
°C
+5
$T_S - T_M$
0
–5
–10
Lamb deaths –
2
4
2
1977
+10
$T_S - T_M$
0
–10
Short–period
Thermal Stress